High Resolution Model Simulation for C3VP, *MC3E*, *IFloodS*, IHPEX, and LPVEx: Comparison with Observations

W.-K. Tao, D. Wu, S. Lang, T. Iguchi, T. Matsui, X. Li,
C. Peters-Lidard, W. Petersen, S. Rutledge

Website for mesoscale modeling group and cloud library
http://cloud.gsfc.nasa.gov/

Goddard Cloud Resolving Models

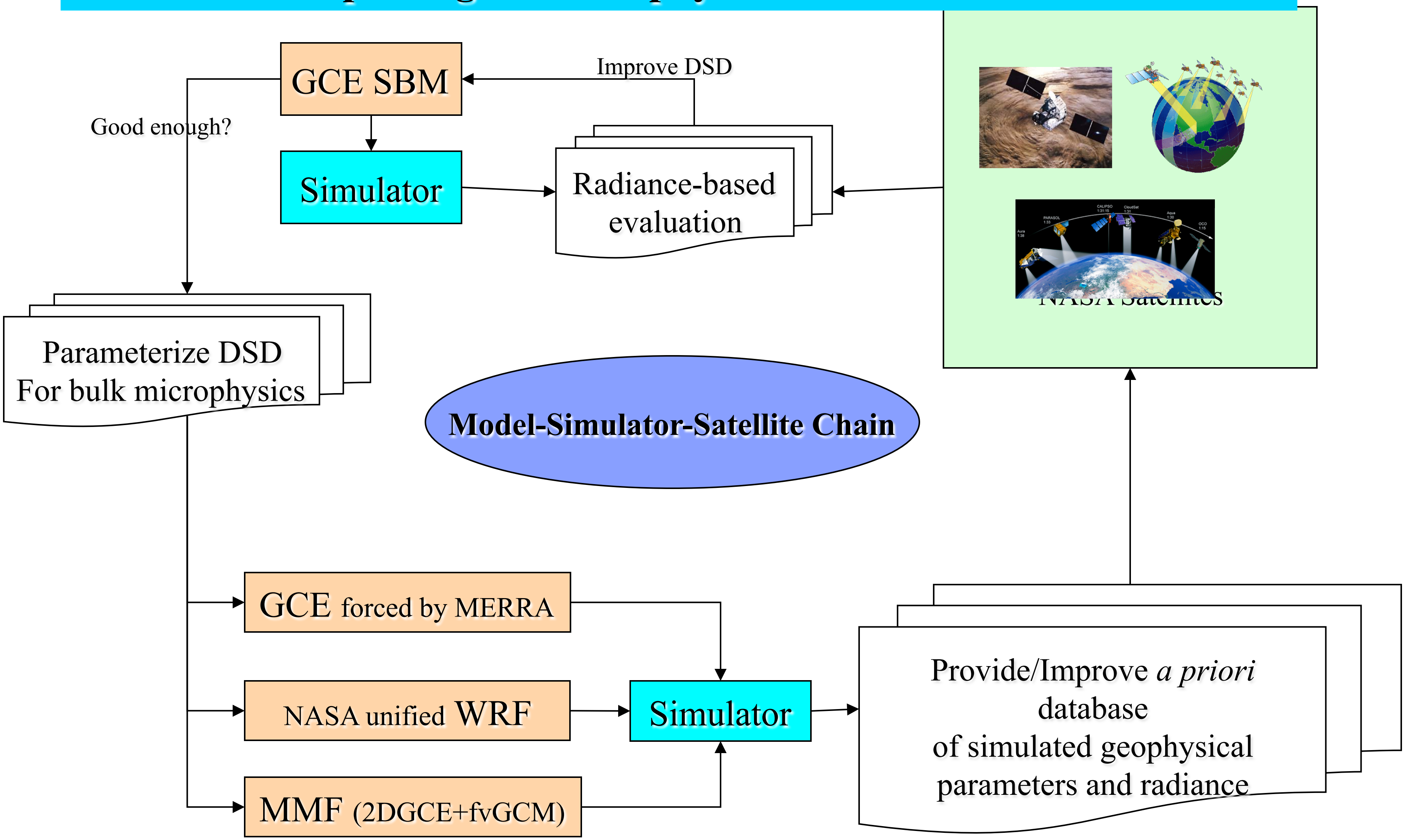
Microphysics Improvements - PMM (TRMM, GPM GV) TRMM (2+1 papers)

C3VP (2 papers), LPVEx (1 paper)

MC3E (5+1 papers), IFoodS (1), IPHEX: Real Time and Post Mission Simulations

Two Posters: LPVEx (T. Iguchi et al.), MC3E, IFloodS, IHPEX (Tao et al.)

Schematic diagram showing the model-simulator approach for improving the microphysics for satellite missions

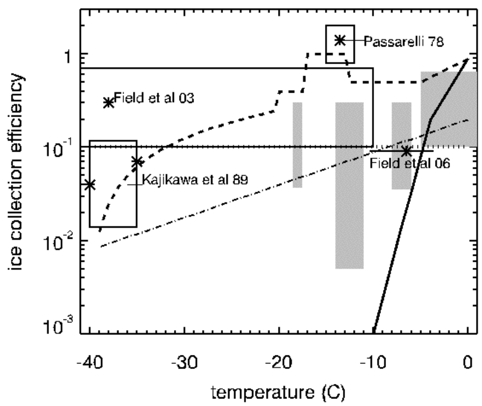


MERRA: Modern ERA Retrospective – Analyses for Research and Applications (1979-2015)

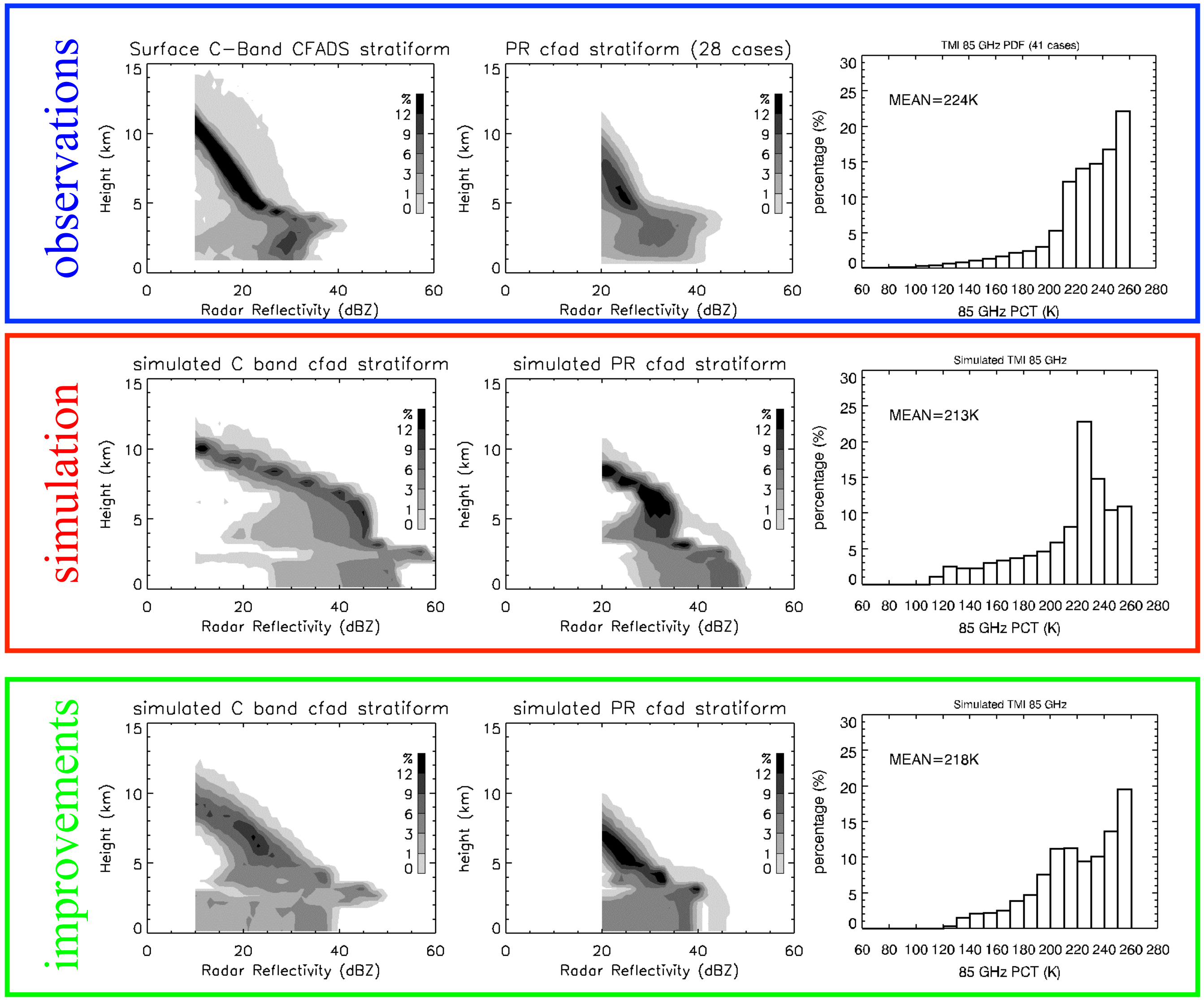
SBM: Spectral Bin Microphysics
WRF: Weather Research Forecast
MMF: Multi-scale Modeling Framework

Improving spectral bin scheme using TRMM satellite data

Ice particle collection efficiency



Ground-based Radar **Space-based Radar** **Microwave (TB)**



Bin model improvements:

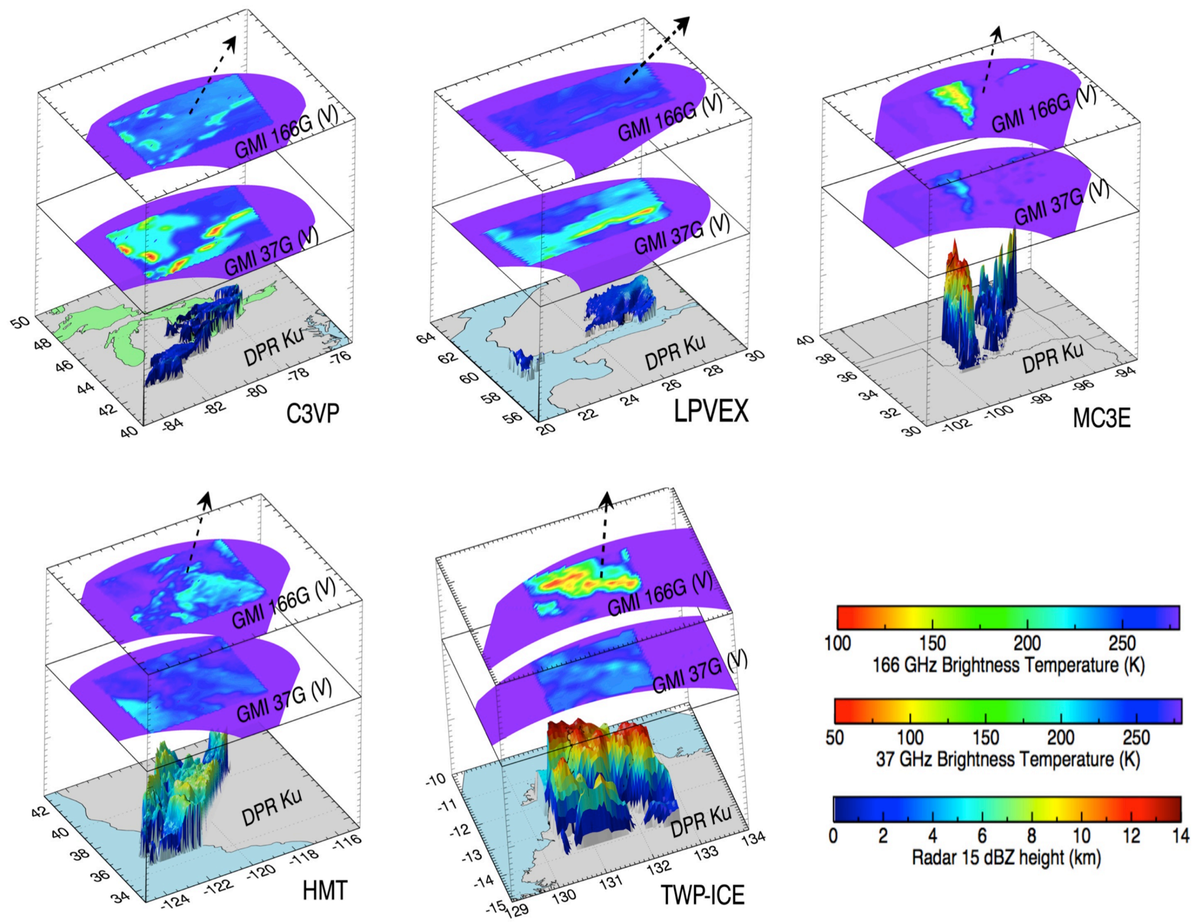
1. Reduce temperature dependent **ice particles collection efficiencies**;
2. Adjust **graupel production** terms when **snow aggregates or ice crystals collect cloud droplets.**

Li, X., W.-K. Tao, T. Matsui, C. Liu and H. Masunaga, 2010: Improving spectral bin microphysical scheme using **TRMM satellite observations**. *Quart. J. Roy. Meteor. Soc*. 136, 382–399.

Synthetic GPM Simulator

1. WRF-SBM simulations were used to generate observable signals from the GPM satellite before launching.

2. Supporting algorithm development, and GPM simulator (forward model) will support CRM evaluation/ development and data assimilation.

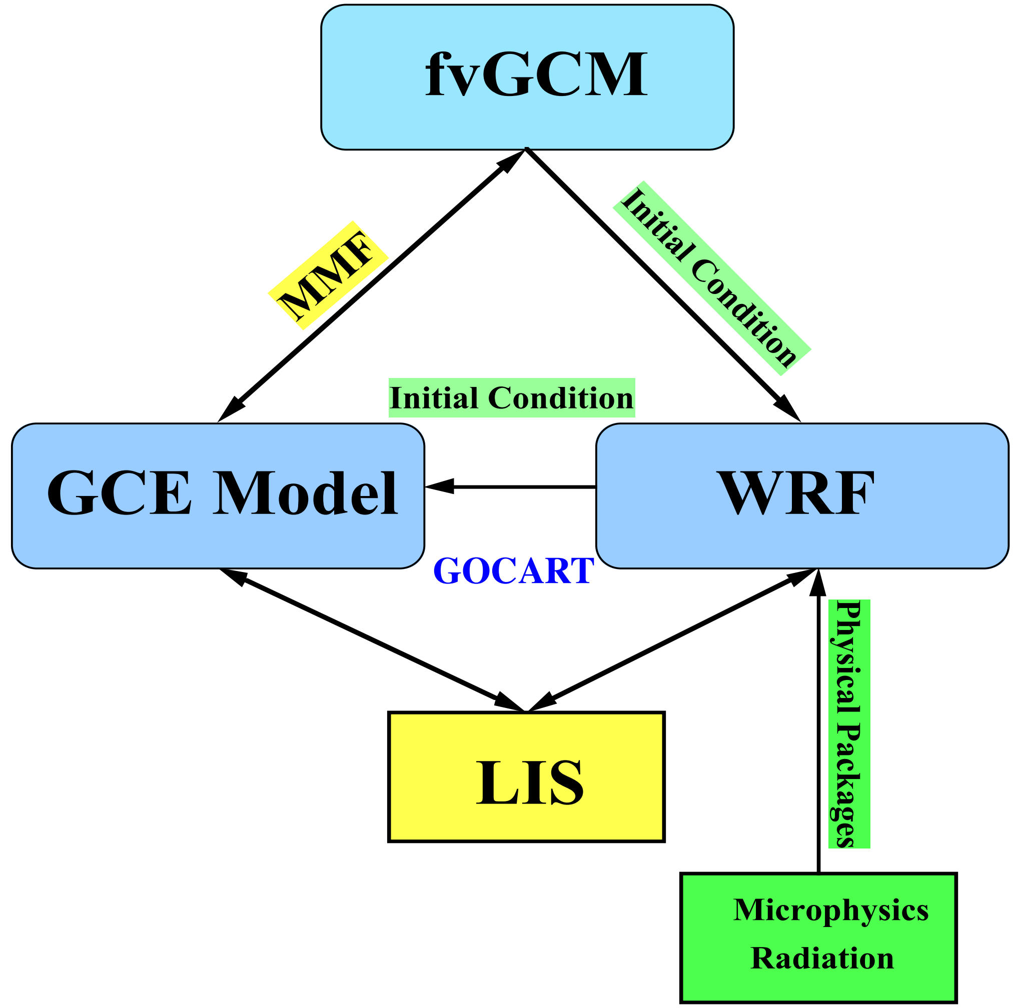


Matsui, T. T. Iguchi, X. Li, M. Han, W.-K. Tao, W. Petersen, T. L'Ecuyer, R. Meneghini, W. Olson, C. D. Kummerow, A. Y. Hou, M. R. Schwaller, E. F. Stocker, J. Kwiatkowski (2013), GPM satellite simulator over ground validation sites, Bulletin of the American Meteorological Society 2013 ; e-View doi: http://dx.doi.org/10.1175/BAMS-D-12-00160.1

NASA Cloud Resolving Models

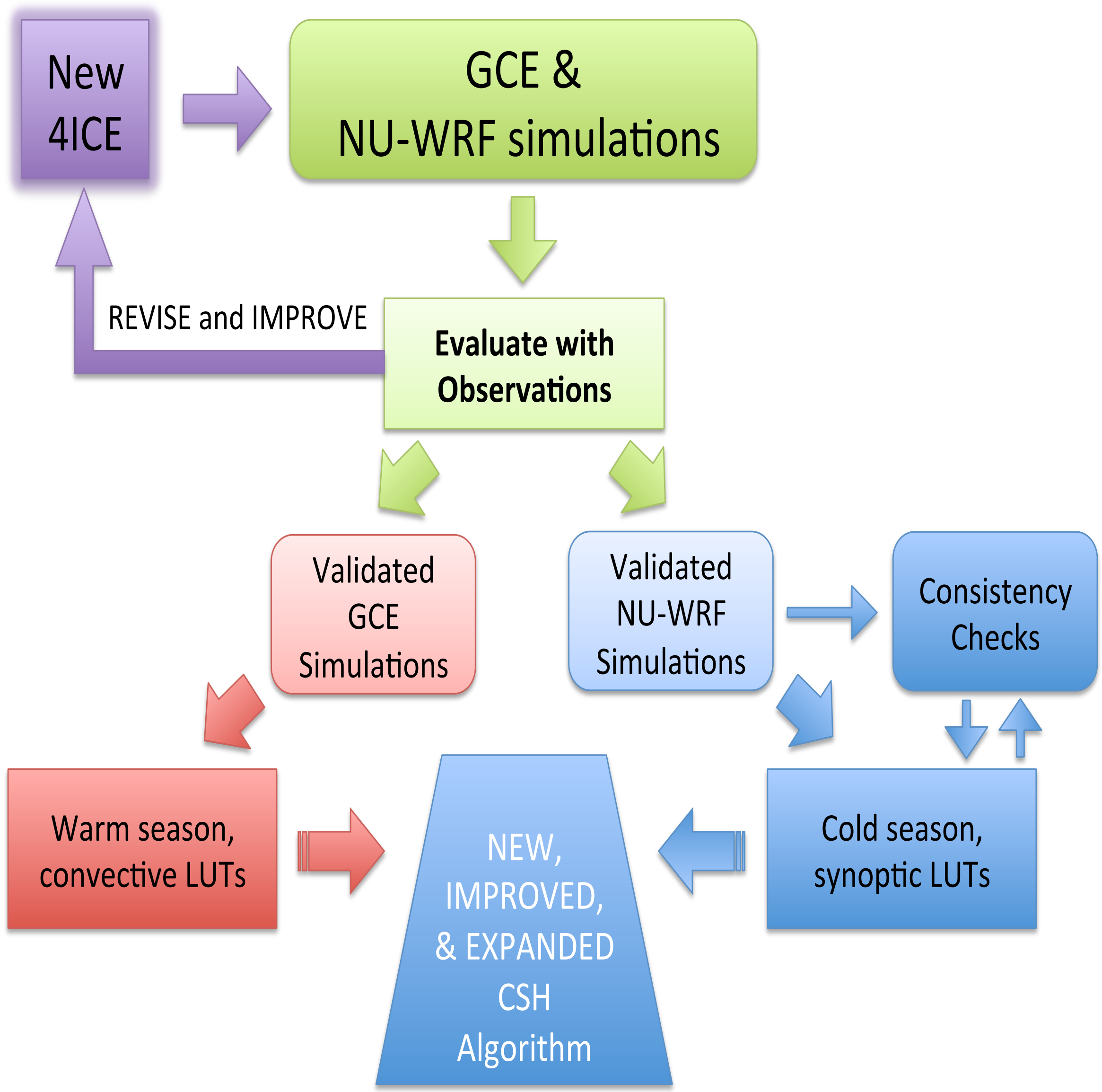
(Tao et al. 2009; 2014)

- **Multi-scale modeling system developed at Goddard with unified physics** from:
  1. **Goddard Cumulus Ensemble model** (GCE), a cloud-resolving model (CRM)
  2. **NASA unified Weather Research and Forecasting Model** (WRF), a region-scale model, and
  3. Coupled fvGCM-GCE, the GCE coupled to a general circulation model (or GCM known as **Goddard Multi-scale Modeling Framework or MMF**).
- Same parameterization schemes all of the models for cloud microphysical processes, long- and short-wave radiative transfer, and land-surface processes, to study explicit cloud-radiation and cloud-surface interactive processes.
- ***Coupled with multi-sensor simulators for comparison and validation of NASA high-resolution satellite data.***



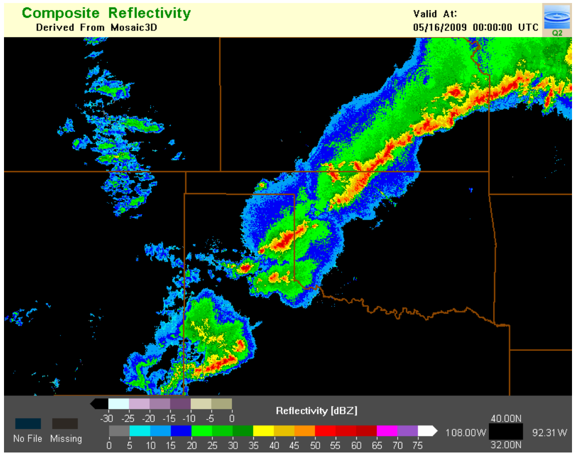
LIS: Land Information System (data assimilation and land surface models)
GOCART: Goddard Chemistry Aerosol Radiation and Transport Model

Use GCE and NU-WRF (GPM GV) for CSH Latent Heating Algorithm Improvements



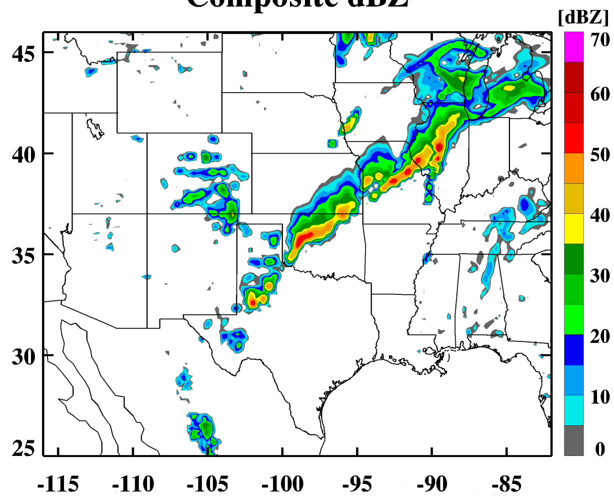
Why do we need to have the 4-ICE scheme?

Observation



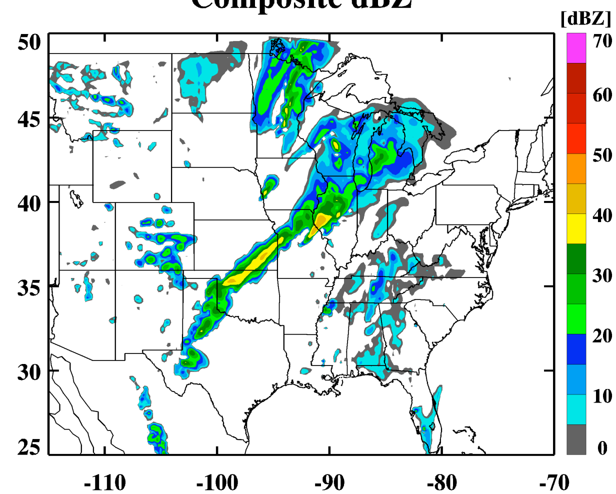
3ICE-Hail

Composite dBZ



3ICE-Graupel

Composite dBZ



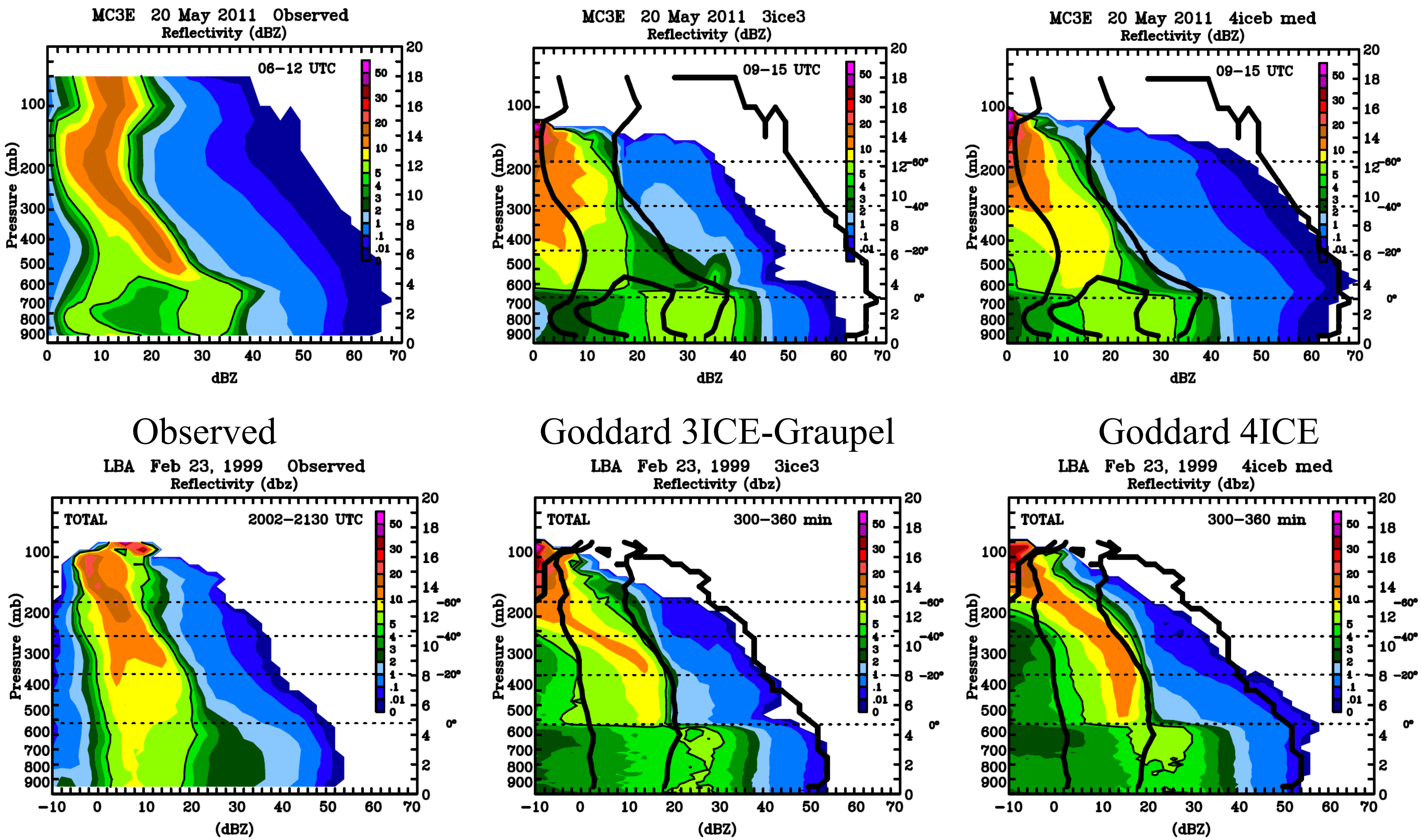
Almost all microphysics schemes are 3-ICE (cloud ice, snow and graupel). Very few 3ICE schemes have the option to have hail processes (cloud ice, snow, graupel or hail)

Both hail and/or graupel can occur in real weather events simultaneously, therefore a 4ICE scheme (cloud ice, snow, graupel and hail) is required for real time forecasts (especially for high-resolution prediction of severe local thunderstorms, mid-latitude squall lines and tornadoes)

Current and future **global high-resolution cloud-resolving models need the ability to predict/simulate a variety of weather systems** from weak to intense (i.e., tropical cyclones, thunderstorms) **over the globe**; this requires the use of a 4ICE scheme

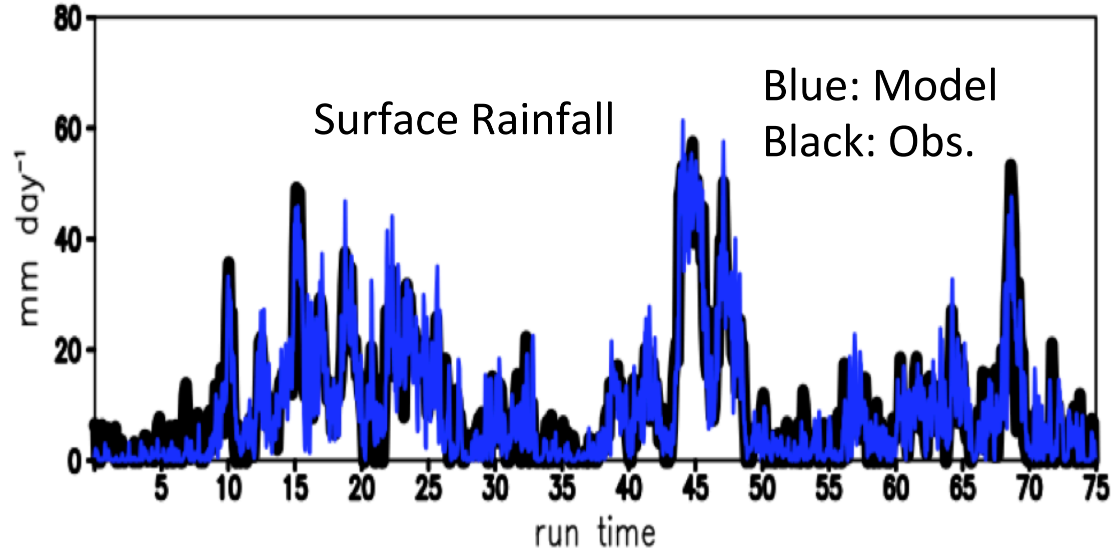
Observed and *GCE* Modeled CFADs

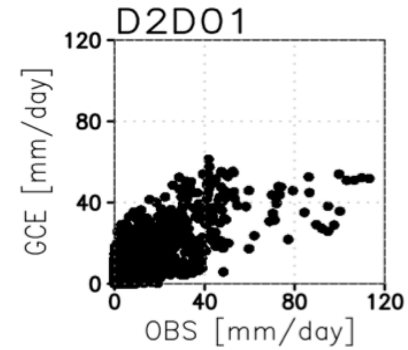
May 20 MC3E (top 3 panels) and Feb 23 LBA (bottom 3 panels) cases



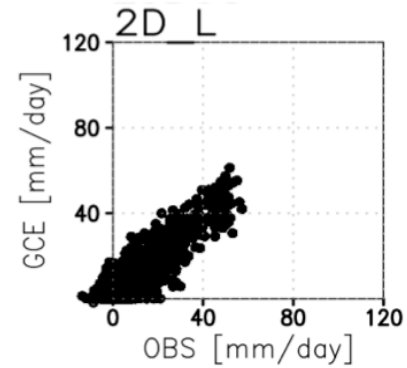
Lang, S., W.-K. Tao, J.-D. Chern, D. Wu, and X. Li, 2014: Benefits of a 4th ice class in the simulated radar reflectivities of convective systems using a bulk microphysics scheme, *J. Atmos. Sci.,* **71**, 3583-3612.

DYNAMO

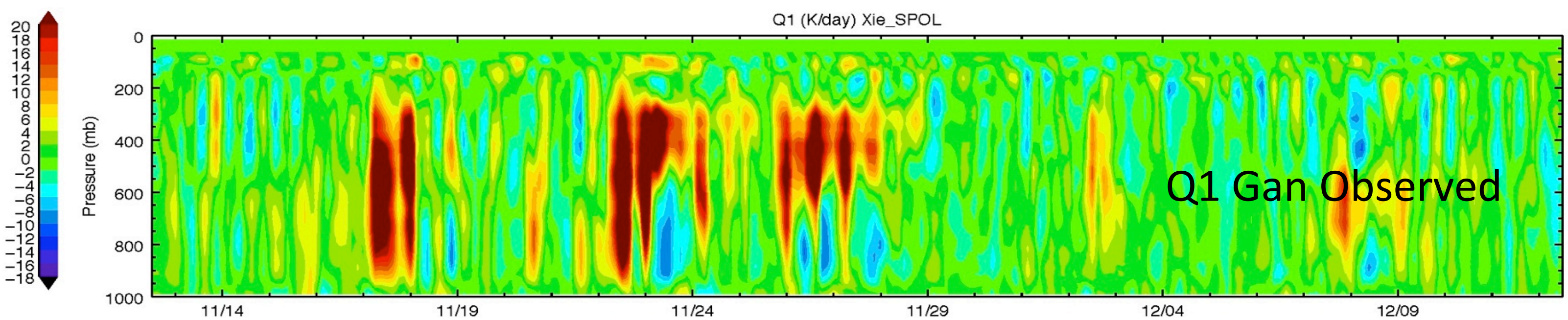


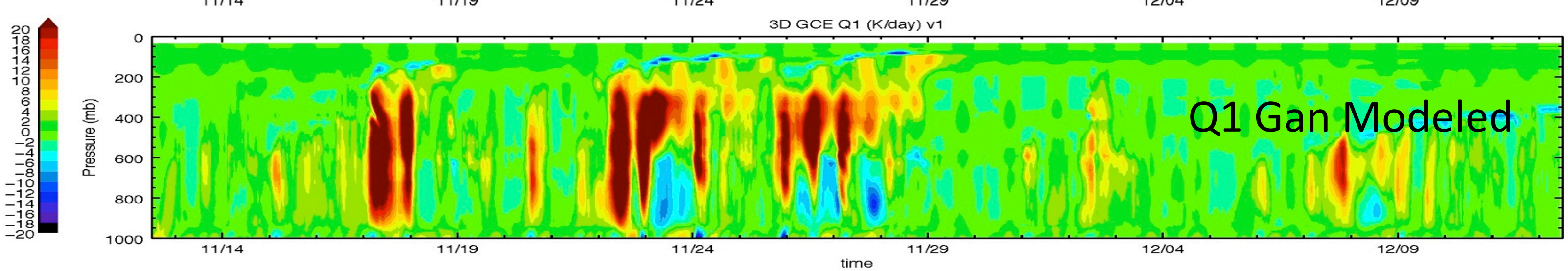


3ICE



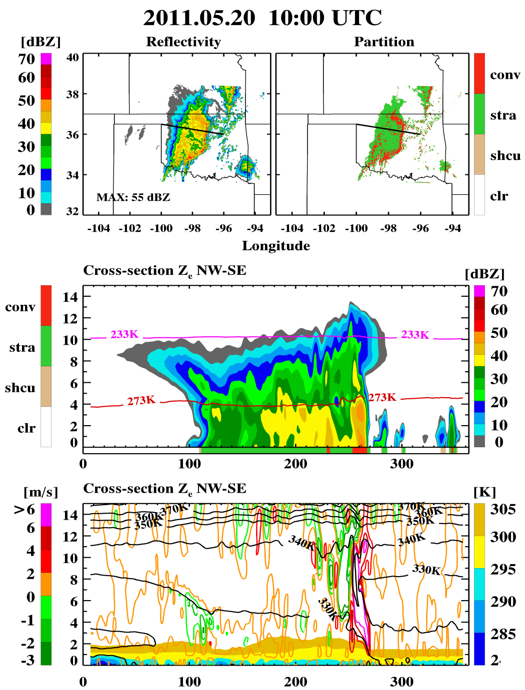
4ICE



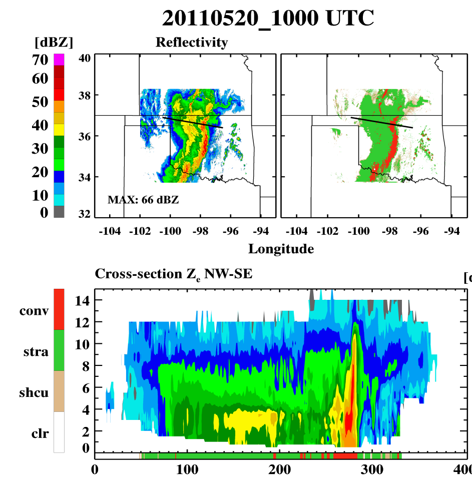


Tao, W.-K., D. Wu, S. Lang, J. Chern, A. Frridlind, C. Peters-Lidard, T. Matsui, 2015: High-resolution NU-WRF model simulations of MC3E deep convective-precipitation systems: Part I: Comparisons between Goddard microphysics schemes and observation. *J. Geophys. Rev.*, (revised and submitted)

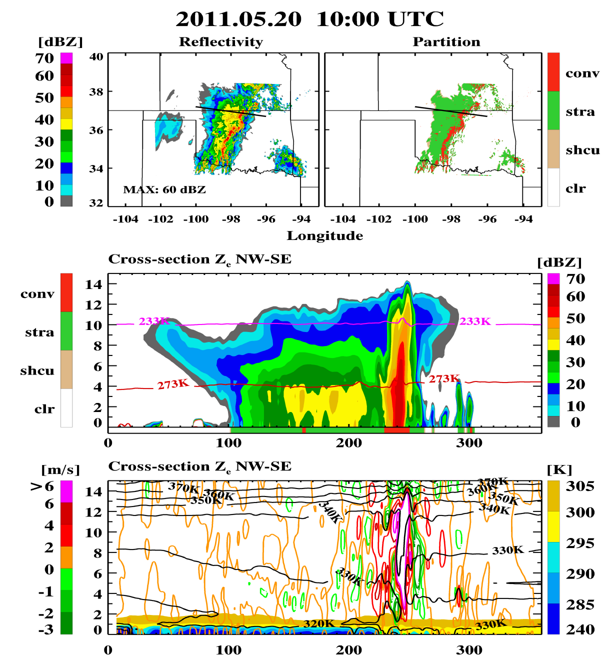
3ICE - Graupel



Observed

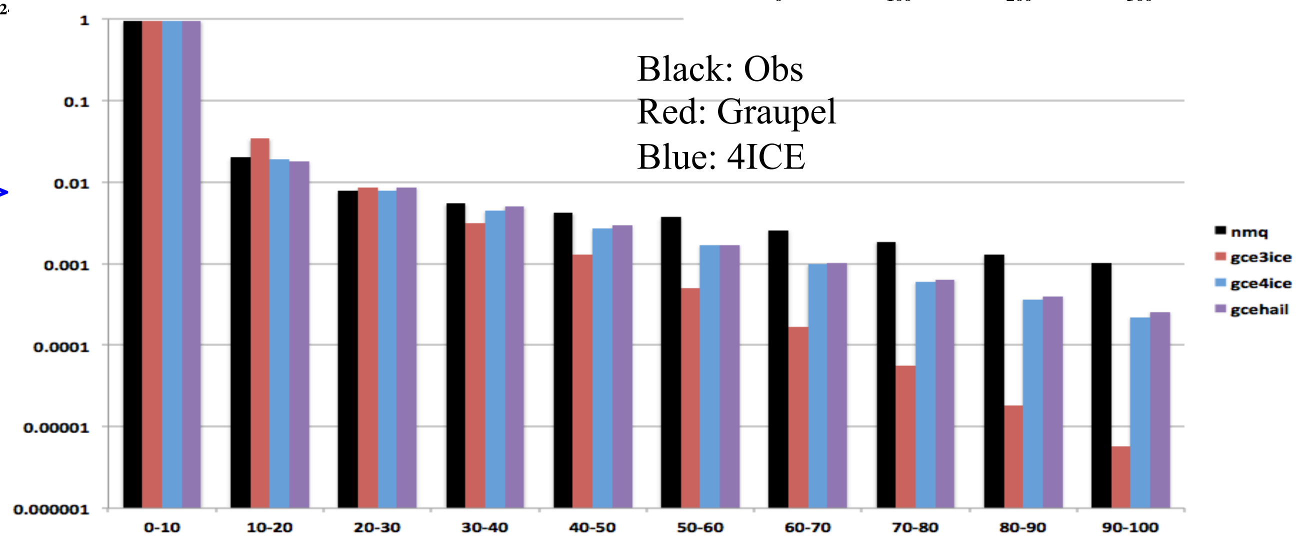


4ICE



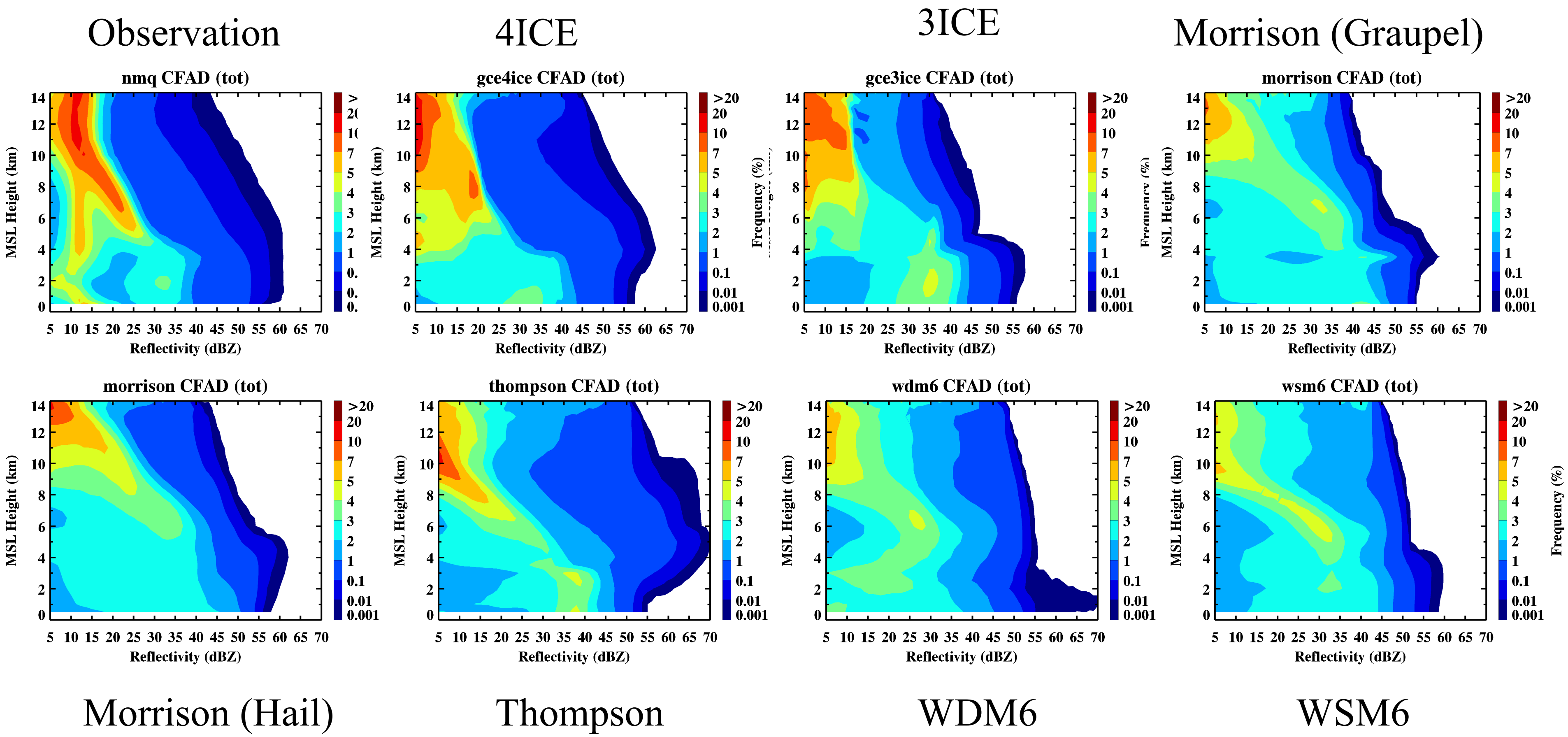
W-velocity
Cool Pool

PDF – Rainfall Intensity >



Both 4ICE and 3ICE-Hail simulated more heavy rainfall than 3ICE-Graupel

Total Contoured Frequency Altitude Diagrams (CFADs)

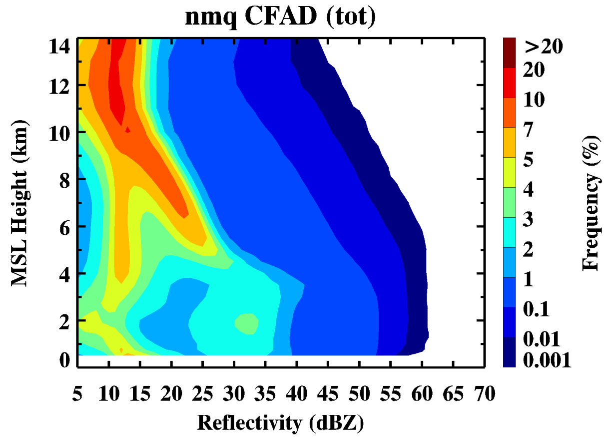


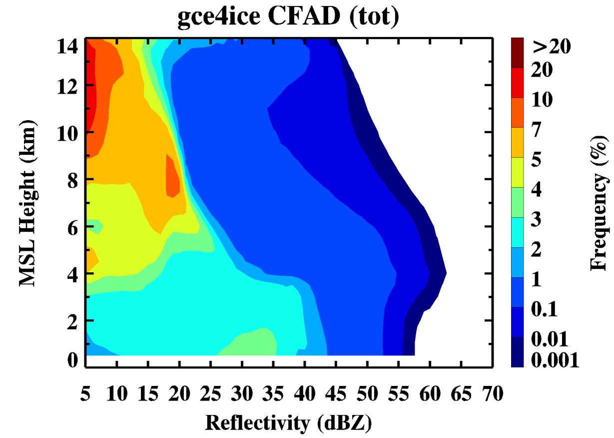
4ICE simulated CFAD agrees very well with observations

Morrison 3ICE-Hail simulated CFAD agrees better with observations than the 3ICE-Graupel schemes (Goddard, Morrison, and WSM6)

Tao *et al.* (2015)
Wu *et al.* (2015)

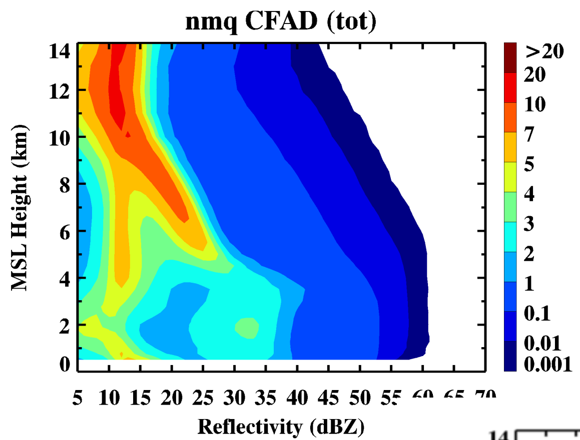
What are the precipitation properties that cause high(> 45 dBZ)and low dBZ (RED) aloft?



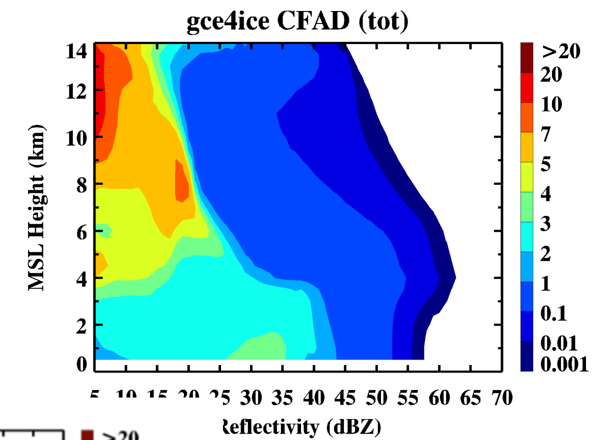


Individual contribution of precipitating particles (rain, snow, graupel and hail) on the CFADs for 4ICE case

What are the precipitation properties that cause high (> 45 dBZ) and low dBZ (RED) aloft?

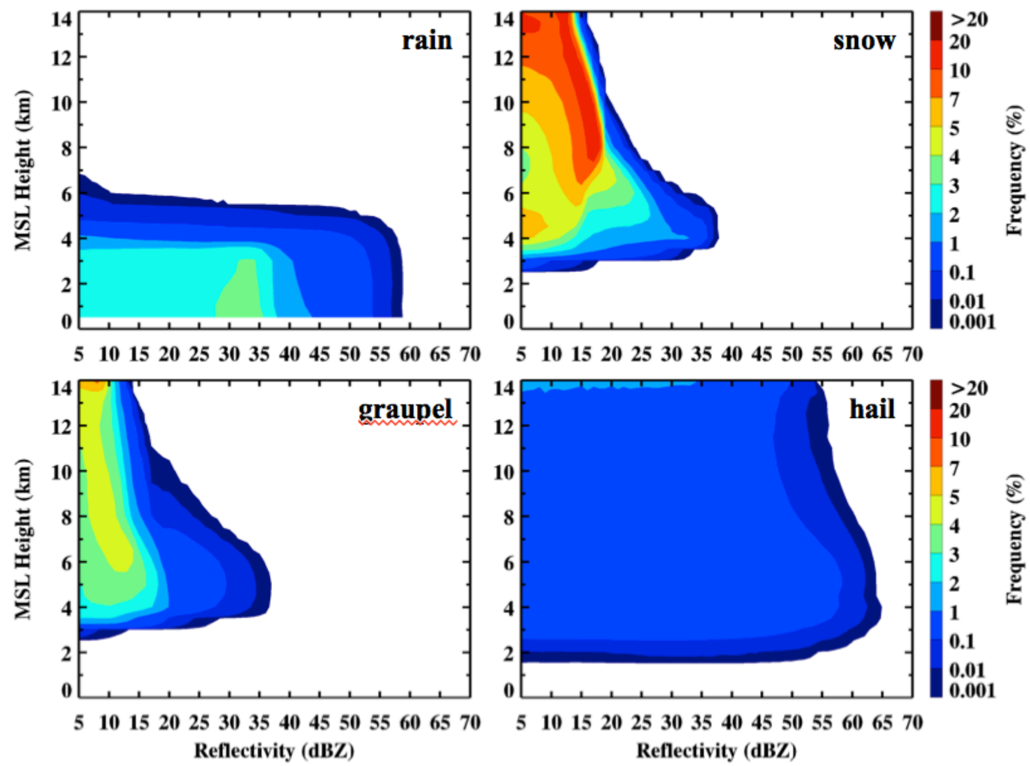


Clearly the snow is the main contributor to the high occurrence of low dBZ and hail is the main contributor for high dBZ aloft.



Rain

Graupel



Snow

Hail

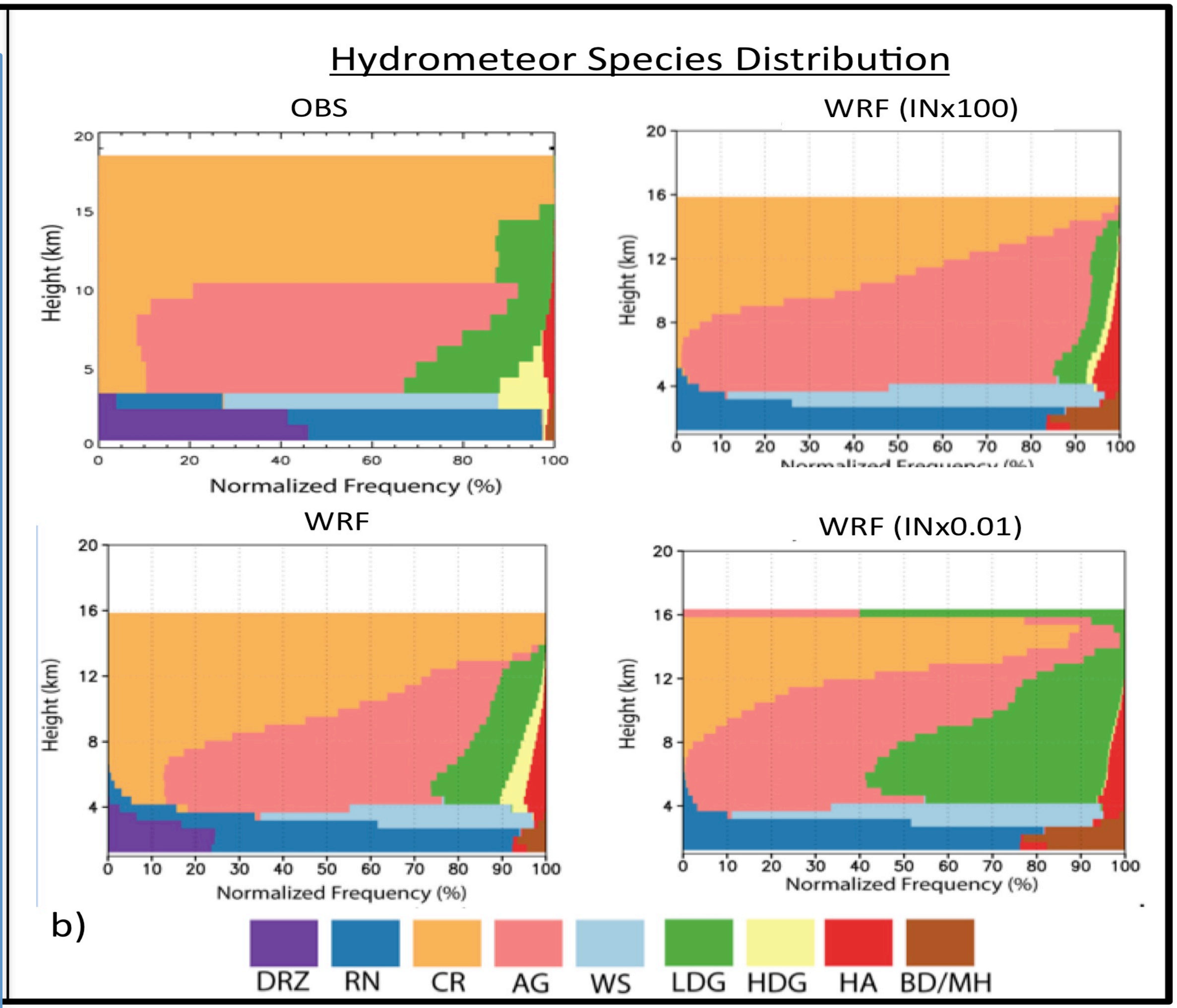
Individual contribution of precipitating particles (rain, snow, graupel and hail) on the CFADs for 4ICE case

WRF-SBM and Polarimetric Radar Observation in MC3E

1. Hydrometeor distributions from WRF-SBM simulations were first time evaluated against the CSU Polarimetric HID retrievals.

2. WRF-SBM closely generated 9 different hydrometeor species to the polariemtric retrievals including heavily rimed particle.

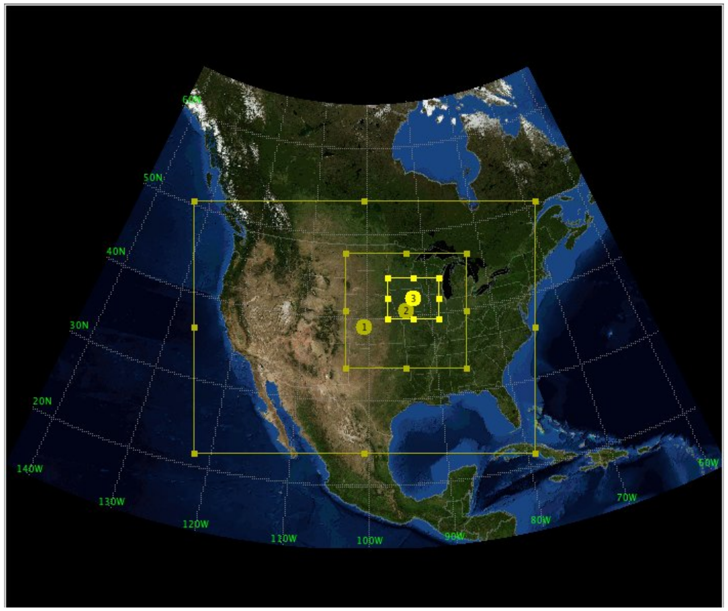
3. Distribution was highly sensitive to the ice-formulating nuclei.



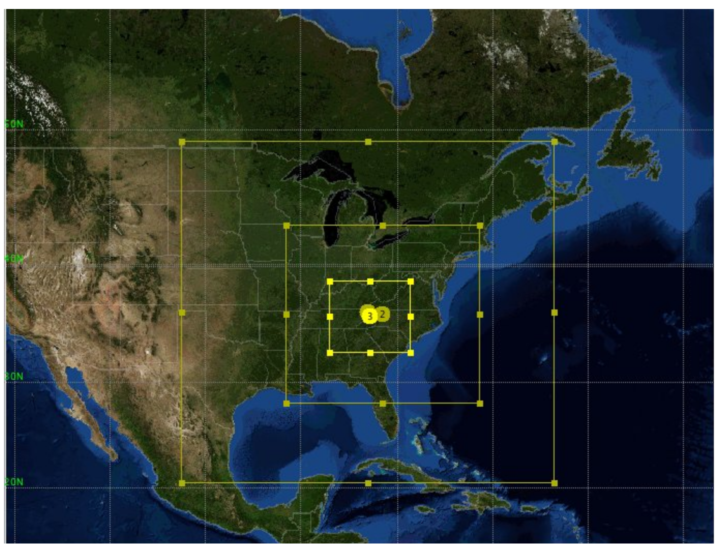
Dolan, B., T. Matsui, A. A. Matthews, S. A. Rutledge, W. Xu, W.-K. Tao, T. Iguchi, V. Chandrasekar, 2015: Multi-sensor Radar Observations and Size-Resolving Cloud Modeling Analysis of the 25 April 2011 MC3E Convective Case, (submitted to MWR)

IFloodS and IPHEX Real Time Forecast – Domain Design

IFloodS
(May 1 - June 15, 2013)
9km(548x402),
3km(583x550),
1km(742x589)

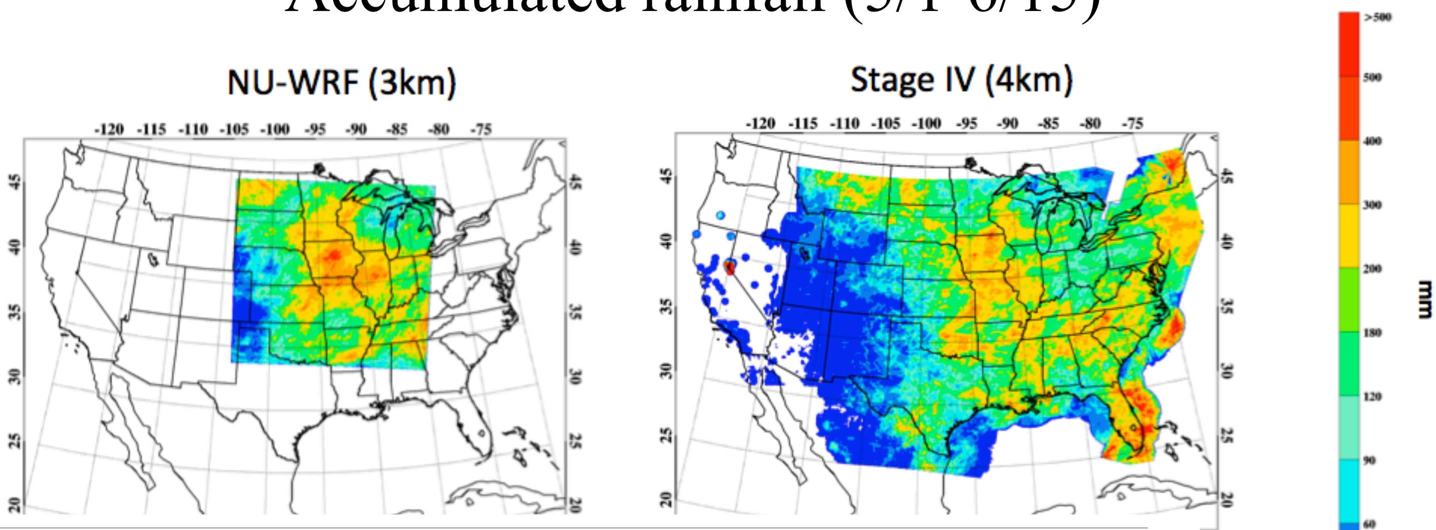


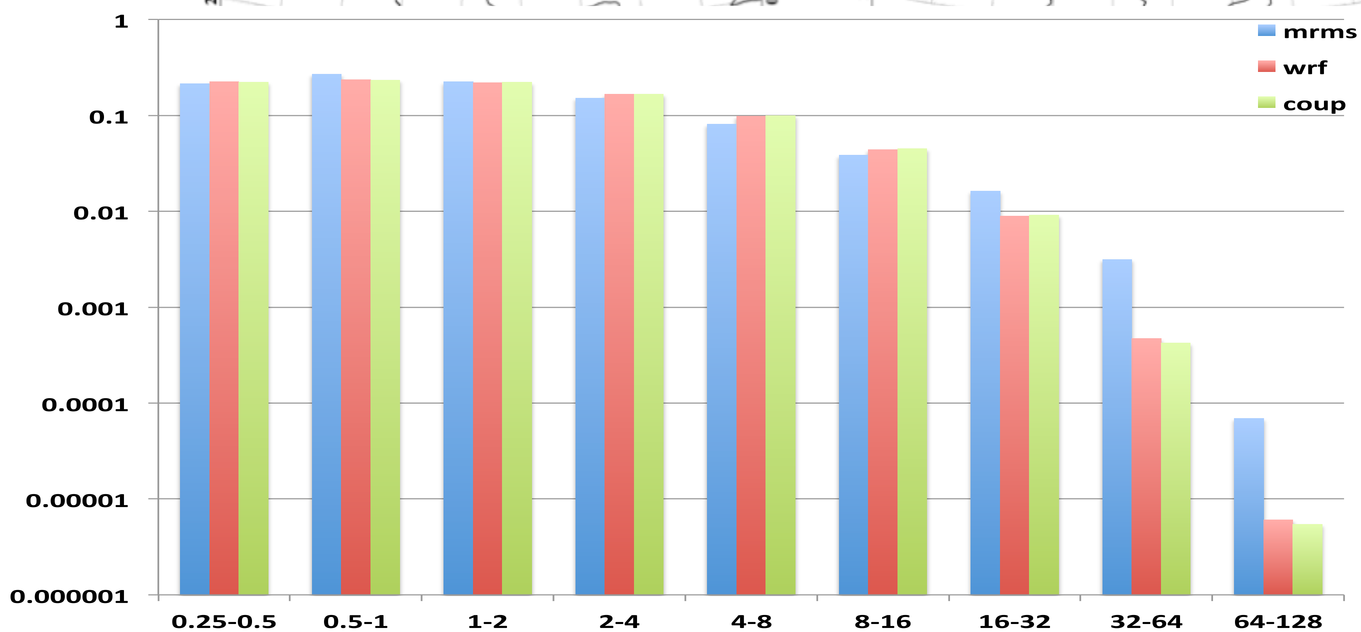
IPHEX
(May 1 – June 15, 2014)
9km(386x353),
3km(601x553),
1km(751x667)



- Three domains
  - with 9km, 3km, **1km** horizontal resolution.
  - 60 vertical layers.
  - 27, 9 and 3 sec time step.
- Physics schemes
  - Goddard Microphysics scheme
  - Grell-Devenyi ensemble cumulus scheme
  - Goddard Radiation schemes
  - MYJ planetary boundary layer scheme
  - Noah surface scheme
  - Eta surface layer scheme
- IFloodS (NAM) and IPHEX (GFS) as input (initial conditions)
- Computational Cost: **2048 CPUs**, takes 7 hours to produce 48 hours forecast.

Accumulated rainfall (5/1-6/15)





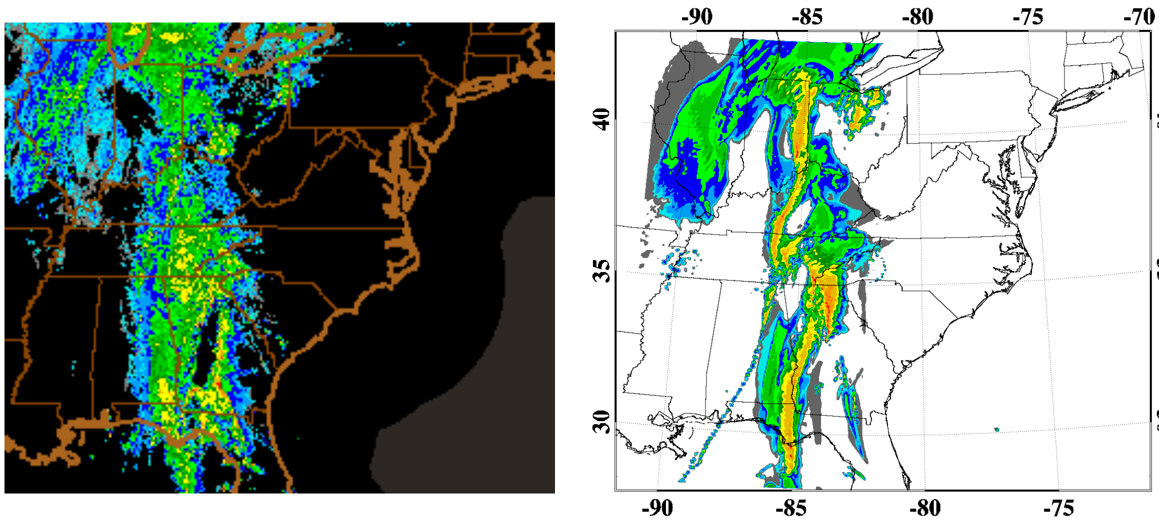
Real Time: 3ICE

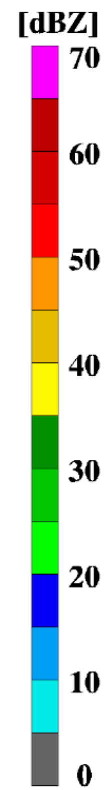
Post Mission: 4ICE

Wu, D., C. Peters-Lidard, W.-K. Tao, and W. Petersen, 2015: Evaluation of NU-WRF real-time rainfall forecast for IFloodS, *J. Hydrometeor*. (to be submitted soon)

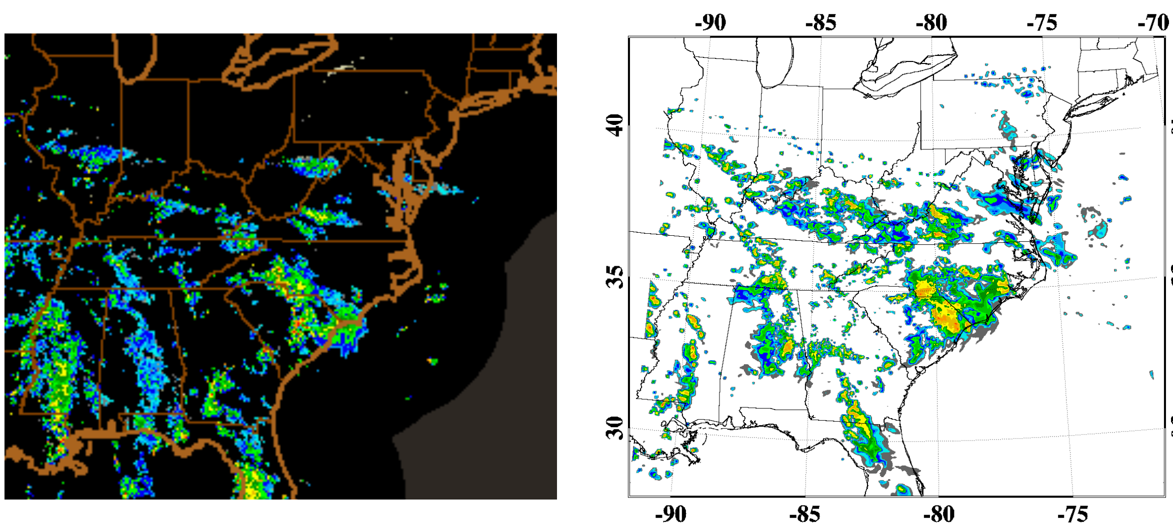
IPHEX (3 Cases: May 15, 23, 30)

20140515 03:00:00 UTC



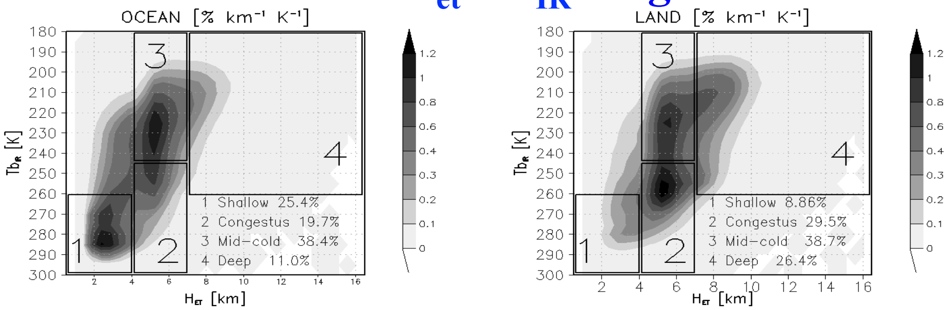


20140530 00:00:00 UTC

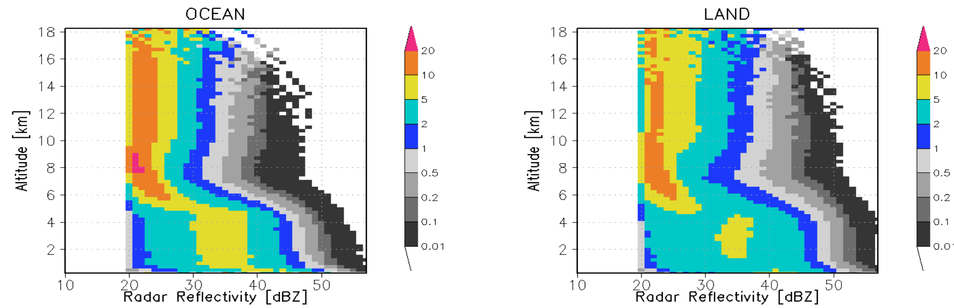


Goddard MMF: 3ICE and 4ICE Evaluation Against T3EF

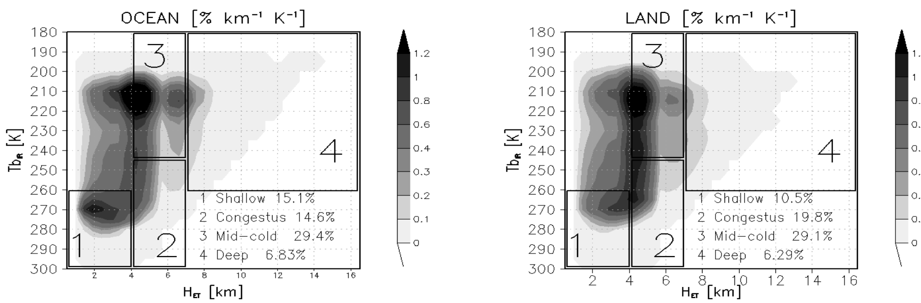
TRMM H_{et}-Tb_{IR} diagram



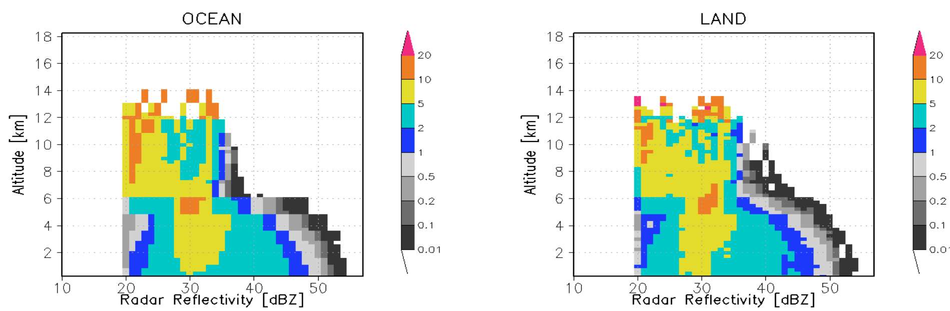
TRMM PR CFADs



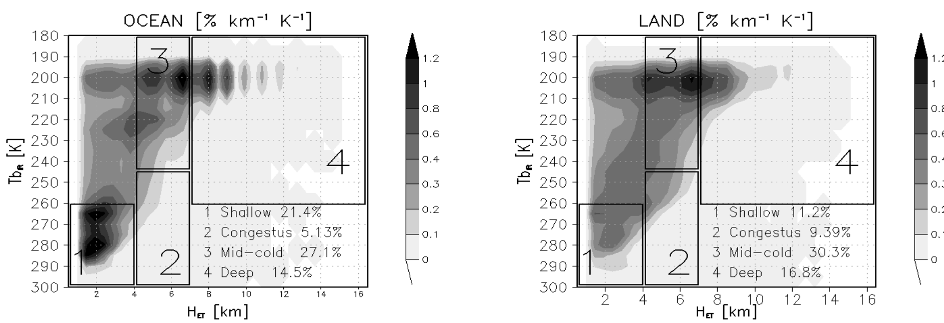
MMF H_{et}-Tb_{IR} diagram

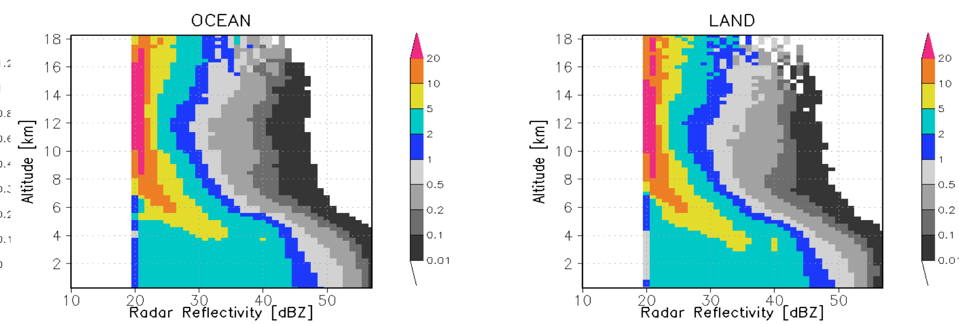


MMF PR CFADs



Goddard 3ICE with Temp-Dependent Snow Size





Goddard 4ICE with 41 vertical layers

On the Land-Ocean Contrast of Tropical Convection and Microphysics Derived from TRMM Satellite Signals and Global Storm-Resolving Models

Matsui, T., , J. Chern, W.-K. Tao, S. Lang, M. Satoh, T. Hashino, and T. Kubota
NASA GSFC Mesoscale Stmospheric Processes Laboratory

One of the most important distinctions of tropical convection and cloud microphysics is the land-ocean contrast.

This study evaluate such contrast through the TRMM statistics composites, **NASA Multi-scale Modeling Framework (MMF), and Nonhydrostatic Icosahedral Cloud Atmospheric Model (NICAM)**.

MMF and NICAM capture that more shallow over ocean and less congestus over land as observed by the TRMM satellites.

However, continental convective vigor is not captured by MMF due to drier boundary layer conditions than NICAM.

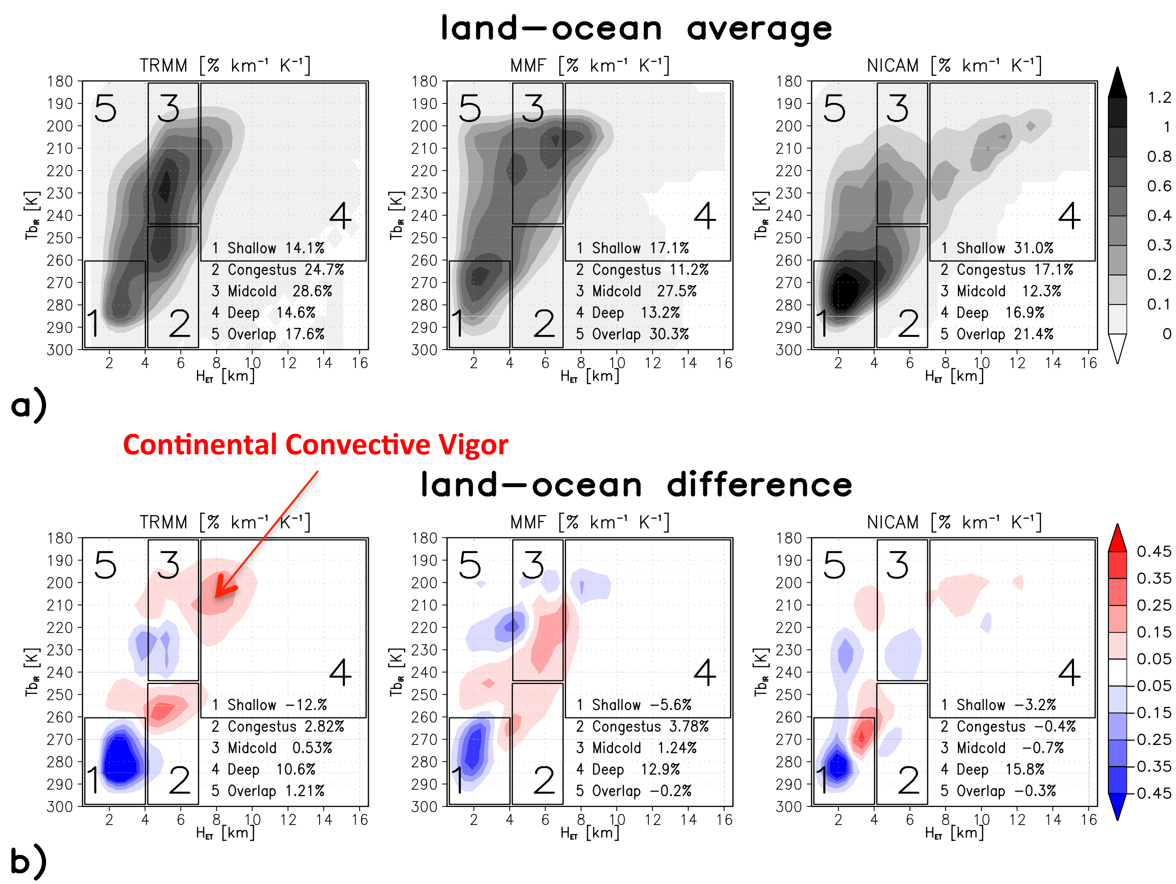


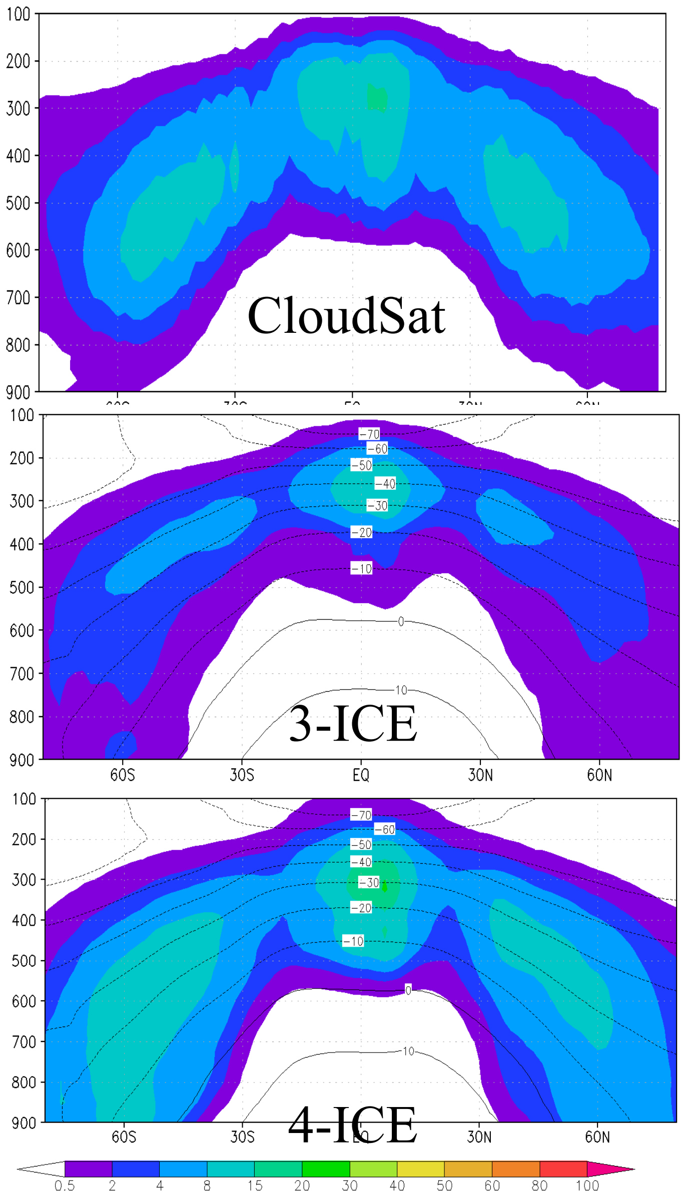
Figure. a) Precipitating cloud classification through the TRMM Tb_{IR} and PR H_{ET} criteria integrated over June 2008 in tropics from the TRMM observation, MMF simulation, and NICAM simulation. b) land-ocean difference in Tb_{IR}-H_{ET} classification diagrams.

Matsui, T., J. Chern, W.-K. Tao, S. Lang, M. Satoh, T. Hashino, and T. Kubota (2015), On the Land-Ocean Contrast of Tropical Convection and Microphysics Derived from TRMM Satellite Signals and Global Storm-Resolving Models, Journal of Hydrometeorology, (submitted)

Field experiment	Location	Period	Reference
GATE	Tropical Atlantic	26 June – 19 September 1974	Houze and Betts (1981)
TOGA-COARE	Equatorial West Pacific	1 November 1992 – 28 February 1993	Webster and Lucas (1992)
SCSMEX (N & S)	South China Sea	2-25 May and 5-22 June 1998	Lau *et al.* (2000)
LBA	Amazonia	1 November 1998 – 28 February 1999	Silva Dias *et al.* (2005)
KWAJEX	Marshall Islands	24 July – 15 September 1999	Yuter *et al.* (2005)
ARM SGP	Oklahoma	1997 and 2002	
TWP-ICE	Darwin	21 January – 12 February 2006	May *et al.* (2008)
DYNAMO	Indian Ocean	11 October – 26 December 2012	C. Zhang (U. Miami)
C3VP	Canada	Winter 2006-2007 20-22 January 2007	Shi et al. (2010); Iguchi et al. (2012)
MC3E	Ponca City, OK	22 April- 3 June 2011 25 April, 1 May, 20 May, 23-24 May,	Tao eat al. (2013, 2015) Iguchi et al. (2012)
LPVEx	Helsinki, Finland	Fall-Winter 2010	Iguchi et al. (2014)
GCPEx	Ontario, Canada	January-February. 2012	
IFloodS	Iowa	1 May-15 June 2013	Wu et al. (2015)
IPHEX	North Carolina	1 May-15 June 2014 15 May, 30 May	A. Barros (Duck U)
OLYMPEX	Olympic Peninsula in the Pacific Northwest	November 2015 – February 2016	R. Houze (U. Washington)
Snow/Frontal Events	Heavy and moderate snow event over East Coast	16 March 2014 February 17, 22 2015	

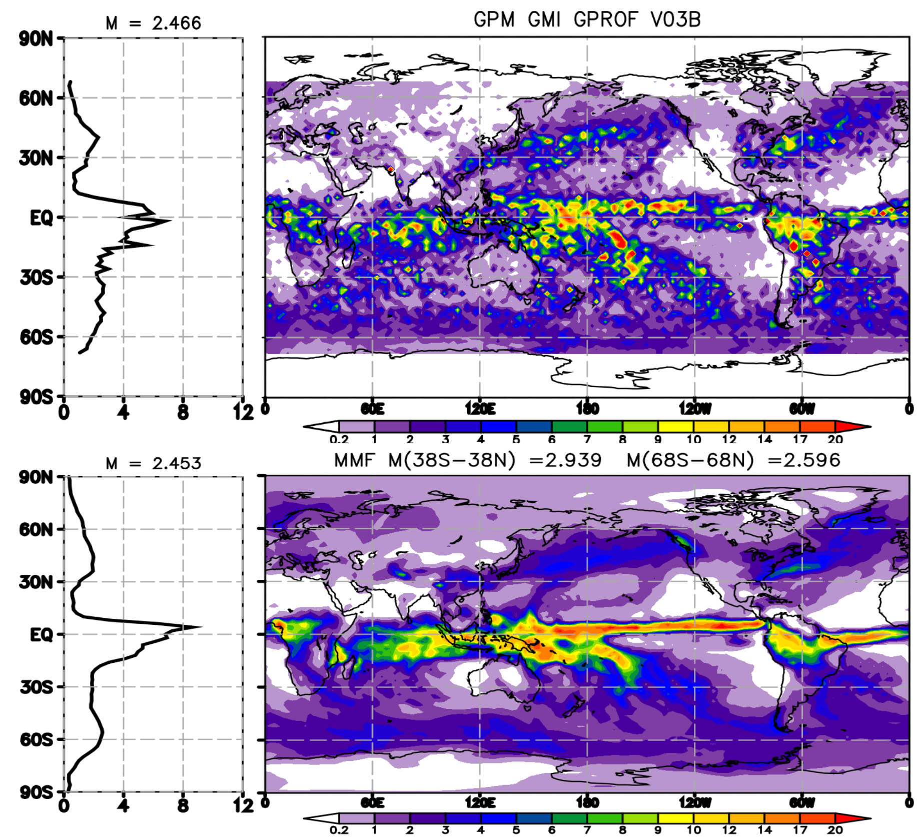
Location, duration and references of key field campaigns. One of the major objectives of SCSMEX, KWAJEX and LBA was to provide forcing for CRMs and validation for TRMM LH profiles. **RED indicates GPM GV field campaigns and snow/frontal events with GPM overpasses**. **BLACK indicates those cases that are currently being used for the CSH look-up tables** and **BLUE cases with available advective forcing (as does MC3E**). Those with specific dates are cases that (1) were simulated, (2) have been published, and (3) are identified to be simulated.

Comparison with CloudSat (annual mean) and GPM (2-month)



GMI GPROF L3 0.25^{o} dataset

MMF 2.5^{o} x 2^{o}

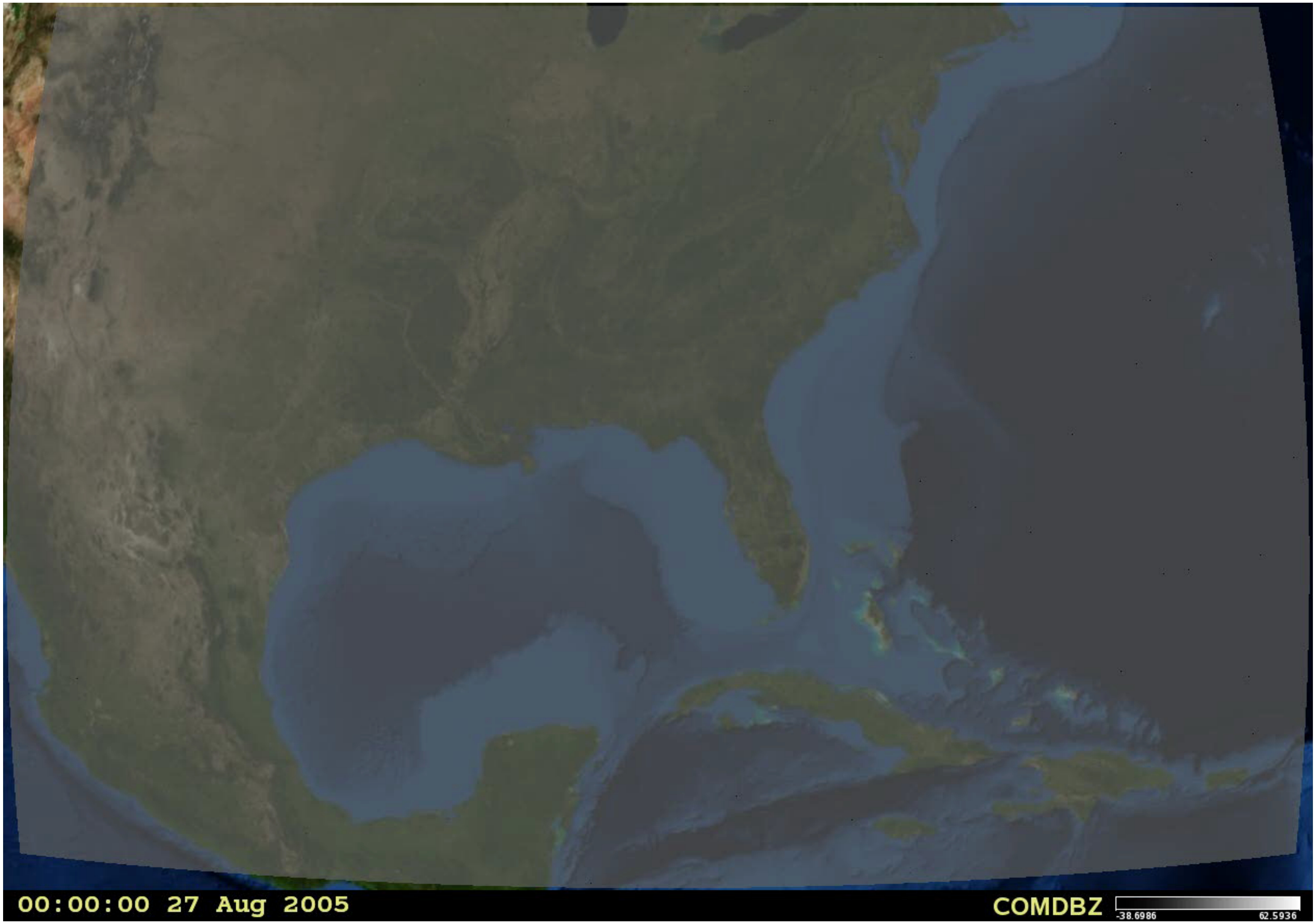


4-ICE has better cloud ice amount extends downward to freezing level in the tropic. 4-ICE has better cloud ice amount in the tropic and mid-latitude but overestimate in the arctic lower atmosphere.

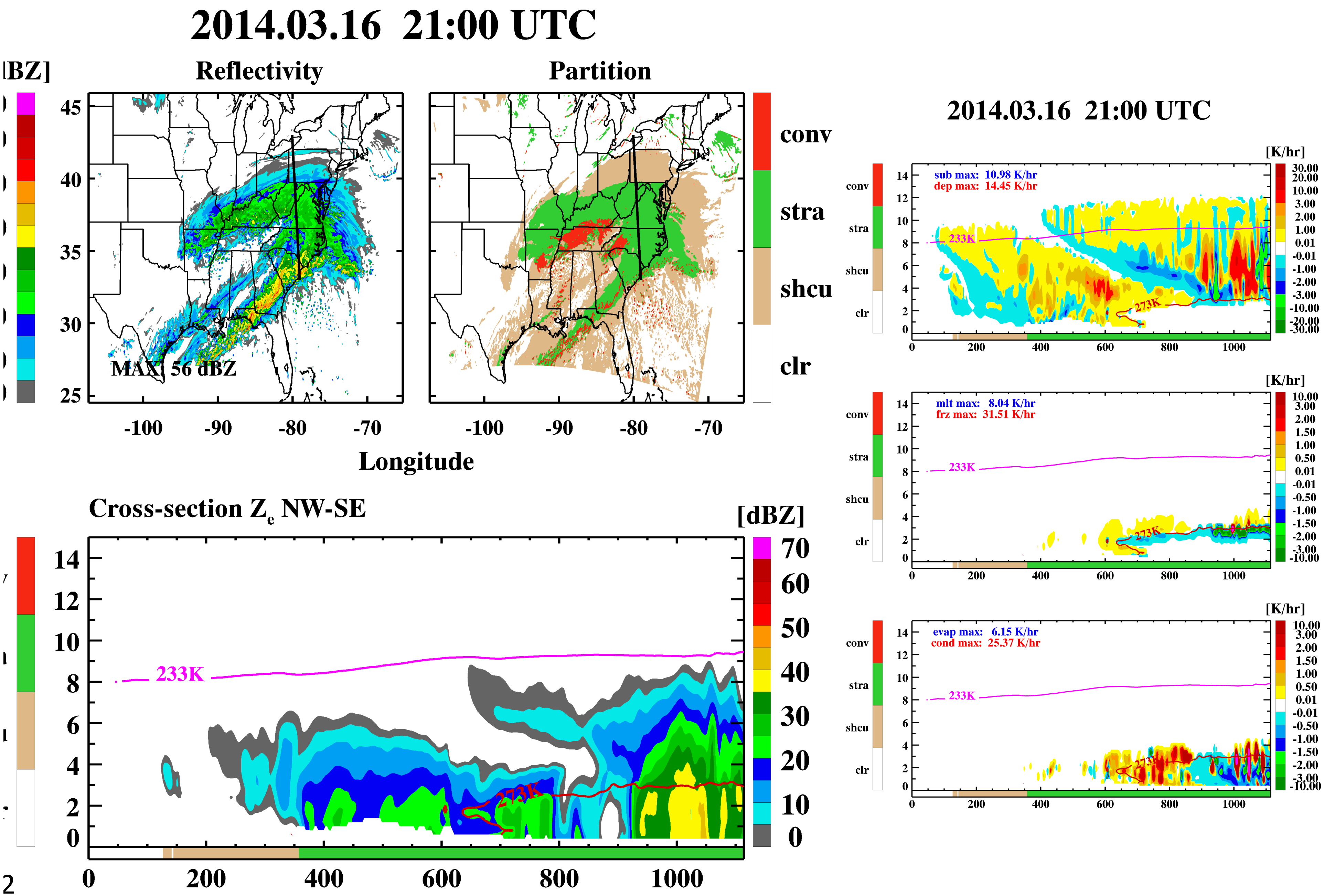
Similar global rainfall amount (2.466 vs 2.453 mm) and overall pattern

Chern, Tao, et al. (2015, accepted)

Hurricane Katrina (2005)
1.67 km grid spacing, 18 second loop



Tao et al. (2011)



2014.03.16 21:00 UTC
Reflectivity
Partition
MAX: 56 dBZ
conv
stra
shcu
clr
Longitude
Cross-section Z_e NW-SE
[dBZ]
233K
273K
2014.03.16 21:00 UTC
[K/hr]
sub max: 10.98 K/hr
dep max: 14.45 K/hr
mlt max: 8.04 K/hr
frz max: 31.51 K/hr
evap max: 6.15 K/hr
cond max: 25.37 K/hr